REMOTE SENSING

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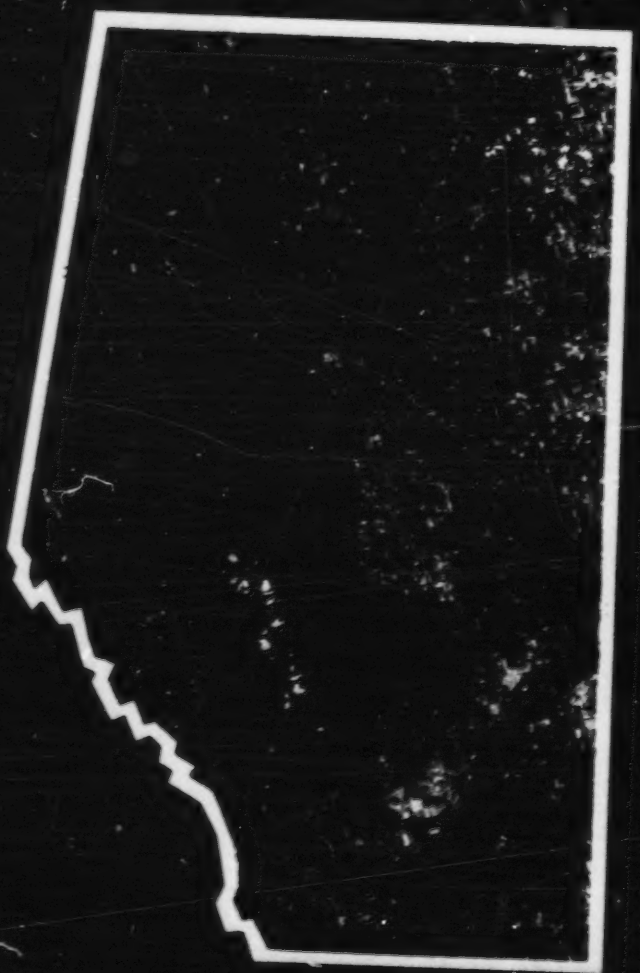

Alberta

GRASSLAND BIOMASS ESTIMATION AND RANGE CONDITION ANALYSIS USING LANDSAT IMAGERY IN FESCUE GRASSLANDS OF WESTERN CANADA

by

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Demonstration Project

This is the abridged edition of a demonstration project report sponsored by the Alberta Remote Sensing Center, Alberta Environment. The complete report is available for in-Center study.

Cover Photograph

Porcupine Hills area, Southwestern Alberta.
Black and white rendition of Landsat C1, 45-25, 09 August, 1981.

ABSTRACT

The study showed that Landsat imagery can provide an accurate estimate of total dry biomass ($r = -.84$). The Landsat vegetation biomass index used in the study was bands 4/4+5+7. Four classes of biomass amounts could be statistically differentiated throughout the biomass range sampled (i.e. 70-320 g/m^2 dry weight) during mid-summer.

Computer maps of the four total dry biomass classes were made for the Agriculture Canada Stavely Research Substation using the Landsat algorithm. Comparison of the Landsat biomass maps with ecological data for fields of known range condition in those areas showed the Landsat method to be highly accurate in estimating range condition. The Landsat system could therefore be used efficiently and cost-effectively for inventorying range condition and monitoring range trend in the rough fescue grasslands of Canada.

CONTENTS

	PAGE
Acknowledgements	iii
Abstract	v
Contents	vi
List of Figures	vii
List of Tables	vii
Introduction	2
Methods	2
Results	3
Landsat Data and Biomass Relationships	3
Range Condition Analysis	6
Summary	7
References Cited	9

LIST OF FIGURES

PAGE

FIGURE 1. Location of the Porcupine Hills study area and the extent of rough fescue grasslands in North America 1

FIGURE 2. Relationship of total dry biomass in rough fescue grasslands to Landsat 3

FIGURE 3. Computer mapping of total dry forage biomass 4

FIGURE 4. Location of fields and ecological habitat types on the Stavely Research Substation. 5

FIGURE 5. Range condition categories determined from computer analysis of total biomass. 6

LIST OF TABLES

TABLE 1. Linear correlations of Landsat digital band values with total wet biomass of native fescue rangeland sites in Southwestern Alberta. 8

TABLE 2. Total dry forage biomass classes, differentiated using an August 2, 1979 Landsat chromaticity ratio 8

TABLE 3. Total dry forage biomass of various range condition categories for rangeland habitat types 8

TABLE 4. Range condition categories identifiable through automatic computer mapping of total dry forage biomass 8

TABLE 5. Areas of range condition categories on the Stavely Research Substation, (Ref. Fig. 5) 8

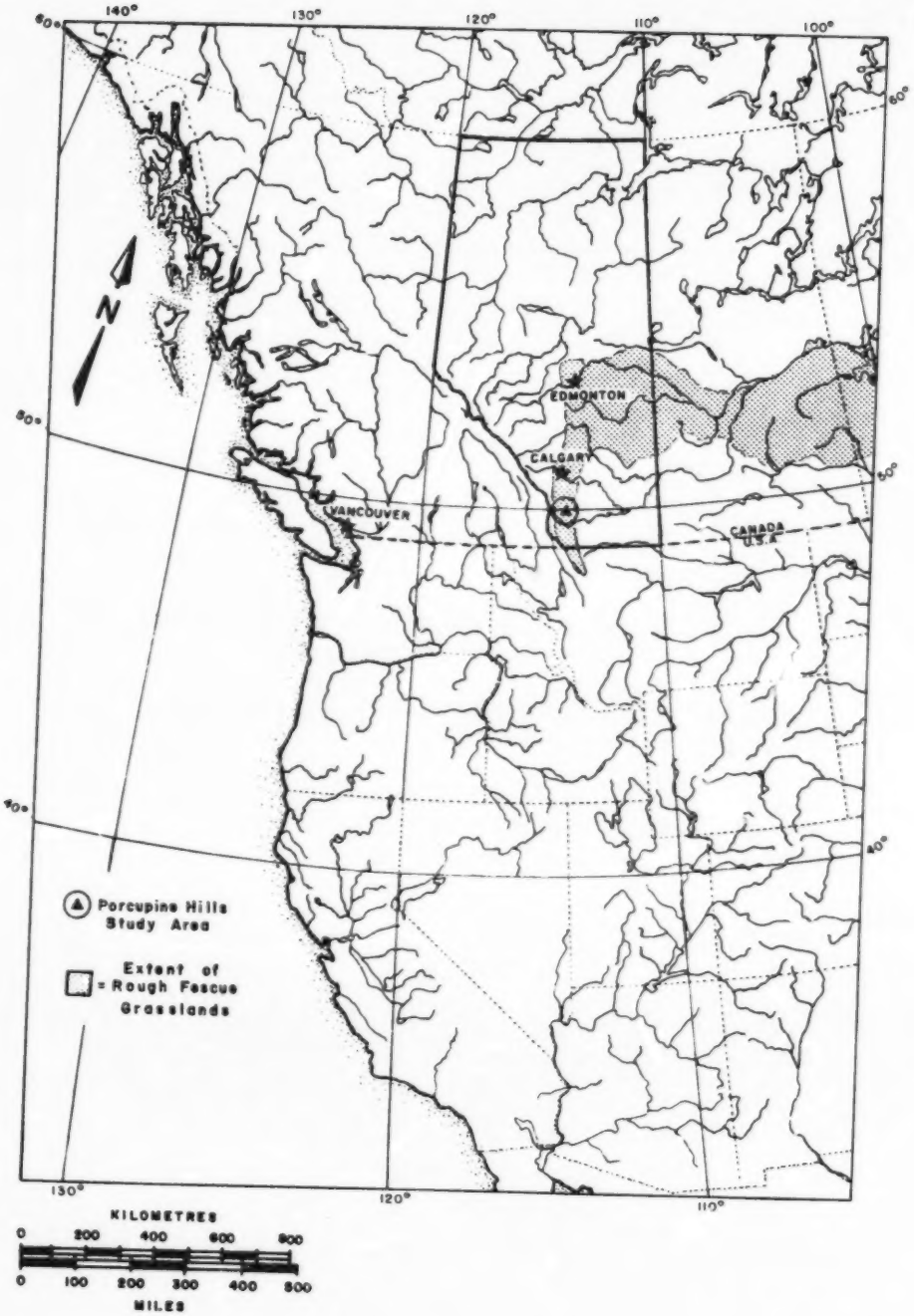


FIGURE 1. Location of the Porcupine Hills study area and the extent of Rough Fescue Grasslands in North America.

1. INTRODUCTION

An accurate method of estimating and mapping total aboveground biomass in grasslands is essential to determine annual range production, evaluate long-term grazing effects on production, monitor reclamation, monitor range rehabilitation projects, and evaluate the results of specific range management practices on range production. Conventional methods of obtaining biomass information involve hand clipping of plots or ocular estimation of biomass corrected by frequent clipping of estimated plots. Both methods are slow, labor-intensive and provide results which can only be applied to small, specific areas. Even methods using capacitance meters (Van Dyne et al. 1968) and the beta attenuation technique (Mitchell 1972), though accurate, require intensive field work and extensive calibration in their application. They, too, are not practical for evaluating extensive areas.

The advent of the Landsat series of satellites introduced new possibilities for environmental data gathering. Computer analysis of the data gathered by Landsat has made possible fast and accurate vegetation mapping of extensive areas of land.

Landsat imagery has been used extensively in the United States to estimate biomass in grasslands. In Canada, no significant results have been reported other than those from the preliminary work of the author (Jaques & Cihlar 1980). The most significant past work includes that of Pearson & Miller (1972), Tucker (1977), and Johnson (1977) in the shortgrass prairies of Colorado; Rouse et al. (1974) and McDaniel & Haas (1982) in semi-desert grasslands of Texas; Bartlett & Klemas (1981) in marshes in Delaware; and Carneggie & DeGloria (1974) in annual grasslands of California. No study has included work in cool-season, mid-grass prairies such as those in western Canada.

A significant limitation of all past studies is that <u>total</u> aboveground biomass has not shown high correlations with any Landsat data. These past studies have demonstrated high correlations with the <u>green</u> biomass component only. Whenever standing dead biomass is included, correlations drop dramatically. Since total biomass, not just the current green portion, must be considered in assessing range condition and production, estimation of the green portion only is of limited value.

The purpose of this study was twofold: 1) to determine if total biomass could be accurately measured from Landsat imagery in the cool-season, mid-grass prairies of western Canada and 2) to determine how the data thus obtained could be applied in evaluation of range condition.

Figure 1 shows the general location of the study area in southwestern Alberta. The Waldron Grazing Co-operative pastures, and Stavely Research Substation (Canada Department of Agriculture) and the Bow-Crow Forest Reserve between these two grazing areas were all covered in the first aspect of the study, which measured biomass. The Stavely Research Substation was specifically selected for the second aspect of the study, the determination of range condition using Landsat imagery.

2. METHODS

To measure the biomass the following methods were employed:

1) Ground information was first collected for comparison with the information provided by the imagery, to check the accuracy of the imagery and its interpretation. Forty-four rangeland sites were selected within the general study area. These were chosen to represent as wide a spectrum of range condition classes as possible for most of the major rangeland ecosystem types previously identified by the author (Jaques & Cihlar 1980). Sampling involved the location of the 44 rangeland sites and placement of a sampling macroplot within each of these sites. The macroplots were 15 x 50 meters in size and were located within each rangeland site so that all biophysical characteristics were as homogeneous as possible within the boundaries of each macroplot. Ten ¼ m^2 microplots were then located at random within the borders of each of the 44 macroplots.

   All aboveground plant material was hand clipped from each of these ten microplots at each of the 44 sites. This sampling work was repeated three times during the growing season of 1979: spring (May 16 - June 1), summer (July 21 - August 8) and fall (September 17 - 27). After every sampling period, each of the 440 samples was sorted into eight forage categories: 1) litter, 2) standing dead grasses and sedges, 3) green grasses and sedges, 4) forbs, 5) shrubs, 6) mosses, 7) lichens and 8) clubmoss. Each sample was then weighed, dried at 48°C for 48 hours, and reweighed.

2) Landsat images of the area were obtained for several 1979 dates as close to the field sampling dates as possible: May 22, August 2, September 7 and September 25. Using the color television monitor to display the imagery, each of the 44 macroplots was located, and the digital value (256 level) of the single Landsat pixel was recorded.

3) All dry and wet weight biomass values were interpolated linearly from the actual date of clipping to the exact date of the Landsat images.

4) Regression analyses were conducted between all categories of biomass data and all possible Landsat band and band ratio values. The significance of difference between means was analyzed

using Duncan's New Multiple Range test (Steele and Torrie 1960).

In the second component of the study the following methods were employed:

1) Total dry biomass values on the optimum date were mapped throughout the Stavely Research Substation using the relationship established in the first component of the study.

2) Forage consumption by domestic animals was added to the total dry biomass mapped in #1 above.

3) The relationships of total dry biomass to range condition categories were established for the major rangeland ecosystem types occurring on the Stavely test area.

4) The range condition of every Landsat pixel was identified and compared with the results published for the Stavely Research Substation (Johnston et al. 1971).

3. RESULTS

3.1 Landsat Data and Biomass Relationships

Table 1 shows the simple linear correlations obtained between the four Landsat digital band values for each date of imagery. Highest correlations were found during the mid-summer date, August 2, 1979. This single date is used in all of the following work.

Total dry forage biomass is one of the most important biomass measurements in practical range management planning. Most research results are published using this parameter. "Total dry forage biomass" includes the dry weights of both green and standing dead material of grasses and sedges, forbs, and shrubs. Mosses, lichens and clubmoss are not included since they are not used as forage. Therefore, total dry forage biomass is the only biomass class considered in the following discussion.

The ratio of Landsat bands 4/4+5+7 provided the highest simple linear correlation with total dry forage biomass (i.e. r= -.79). As shown in Figure 2, the correlation is not actually linear but follows the form $Y = aX^b$, where "Y" is the Landsat ratio value, "X" is the total dry forage biomass value, "a" is a constant and "b" is the common logarithmic exponent. Table 2 shows that, using the logarithmic relationship, four classes of total dry forage biomass can be statistically separated throughout the range of biomass sampled (i.e. 70-320 g/m²) from the August 2, 1979 Landsat image. Figure 3 shows the distribution of each biomass class on and around the Stavely Research Substation as mapped on the August 2, 1979 Landsat image.

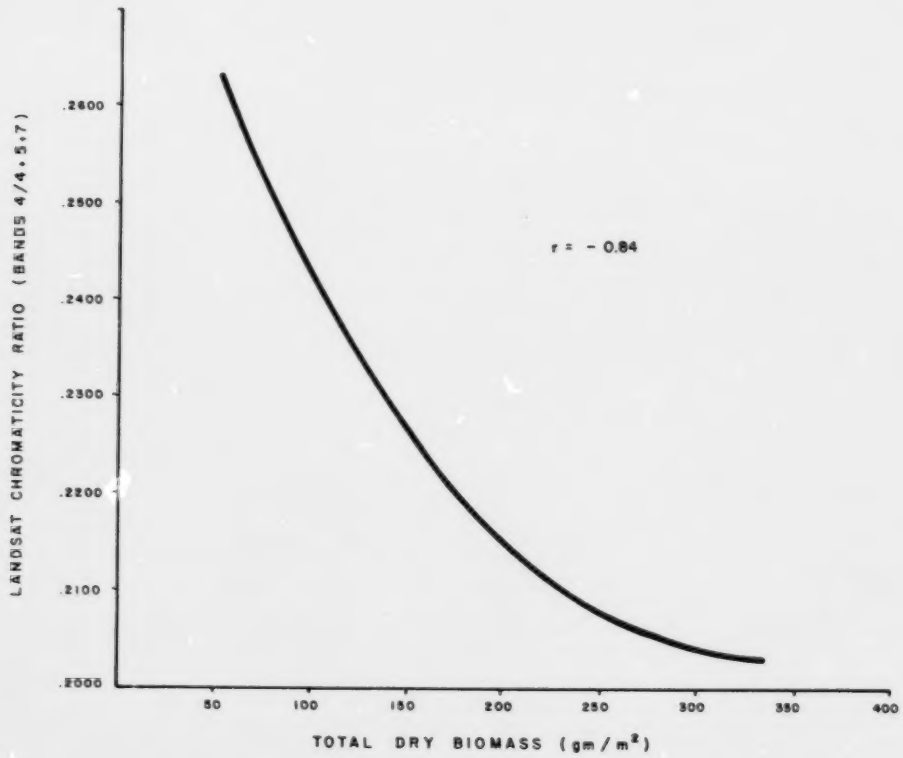
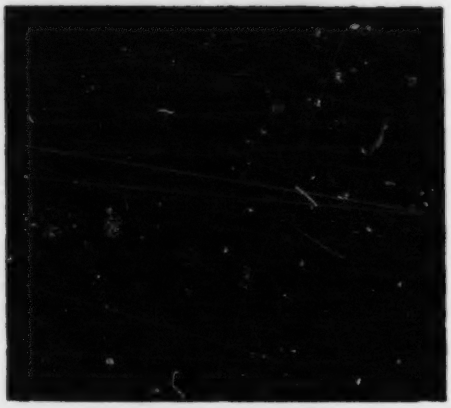


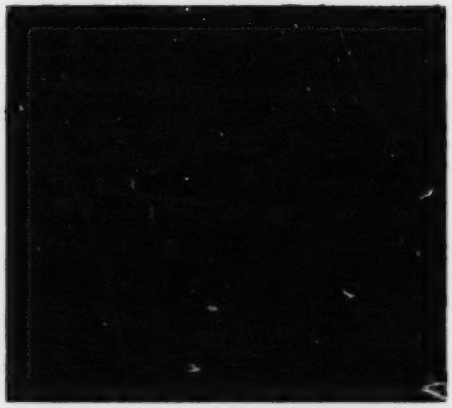
FIGURE 2. Relationship of total dry forage biomass in rough fescue grasslands to Landsat data.

3a. Biomass Class 70-131 g/m^2



3b. Biomass Class 132-193 g/m^2

3c. Biomass Class 194-255 g/m^2



3d. Biomass Class 256-317 g/m^2

FIGURE 3. Computer mapping of total dry forage biomass. (The area shown is the same as in Figure 4b.) Each black square represents the biomass class of one Landsat picture cell ("pixel") and is approximately one acre in size.

LEGEND

1 = Rough fescue - Parry's oatgrass/ Sticky geranium H.T.

2 = Rough fescue - Richardson's needlegrass H.T.

3 = Rough fescue - Idaho-fescue H.T.

4 = Rough fescue - Porcupine grass H.T.

5 = Aspen Woodland

FIGURE 4. Top: Location of Stavely Research Substation. Bottom: Distribution of Habitat Types (H.T.'s). VIEW THIS FIGURE IN CONJUNCTION WITH OVERLAY - INSIDE BACK COVER.

3.2 Range Condition Analysis

Range condition analysis must take into account differences in ecological characteristics of the biophysical habitat types (sensu Daubenmire & Daubenmire 1968) found on any given area. Figure 4 shows the location of the Stavely Research Substation and the distribution of major rangeland habitat types on it. View in conjunction with overlay (inside back cover of this report). Different grassland habitat types can respond differently to the same intensity of grazing use (Jaques 1980, Mueggler & Stewart 1980). For example, in Table 3 one can see that moderate grazing intensity which produces "good" condition range has led to a reduction in total dry forage biomass in the Rough fescue-Idaho fescue Habitat Type compared to the biomass evident in excellent condition sites of that habitat type; while in the other two habitat types the same intensity of use has actually led to an increase in total dry forage biomass when condition changes from excellent to good.

Table 4 combines the Landsat biomass class information given in Table 2 with the biomass values for all range condition categories given in Table 3 to identify the range condition categories which can actually be recognized from the Landsat biomass class maps alone. In the Rough fescue-Idaho fescue Habitat Type all four range condition categories can be estimated from the Landsat biomass maps for all sites of this habitat type. In the Rough fescue-Richardson's needlegrass Habitat Type only three range condition categories can be identified, and in the Rough fescue-Porcupine grass Habitat Type only two.

Figure 5 shows the map results of the interpretation of the Landsat biomass class maps taking into consideration forage utilization and the relationship between biomass and range condition. Extensive areas of each field are in "unknown condition" as shown on Figure 5. These areas are of unknown condition for one of two reasons: 1) The Rough fescue-Parry's oatgrass/Sticky geranium Habitat Type was not sampled for total biomass during the field studies because of time and budget constraints. Therefore, Landsat biomass classes mapped in this habitat type could not be assigned to any definite range condition category. 2) Since all Landsat pixels identified in the three highest biomass classes for the Rough fescue-Porcupine grass Habitat Type could be in either fair, good or excellent range condition (see Tables 2, 3 and 4), it was impossible to assign such pixels to any specific range condition category. All Landsat pixels on this habitat type in these three biomass classes were therefore treated as "unknown condition" sites.

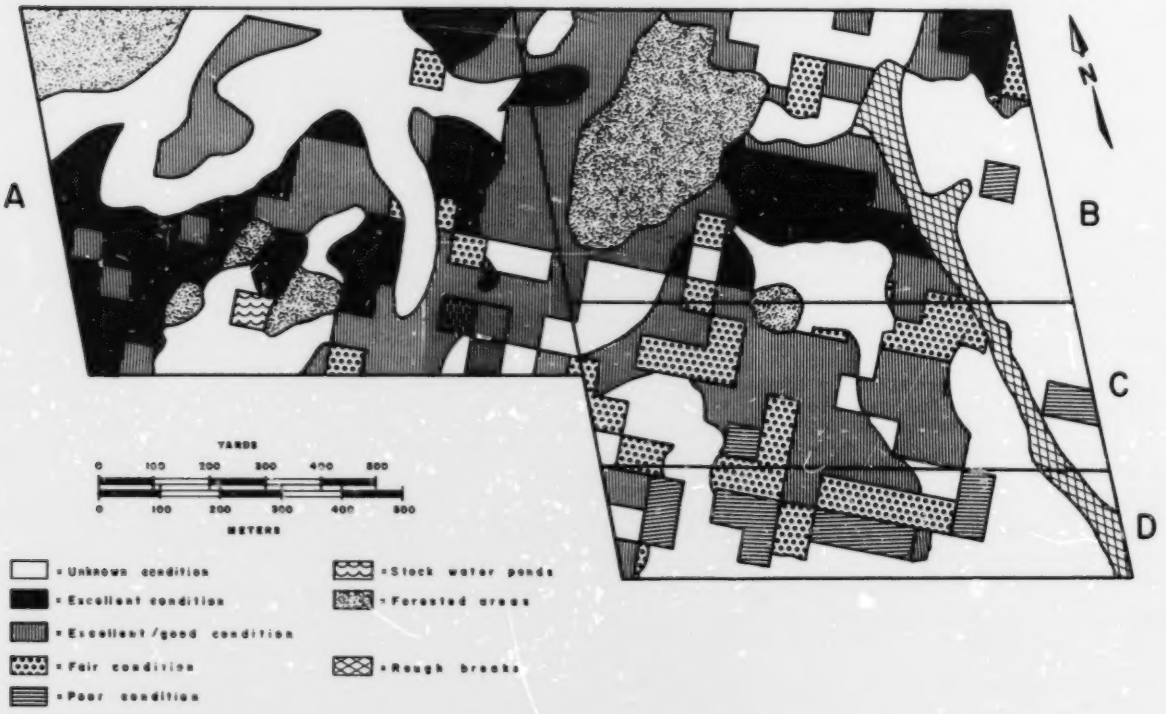


FIGURE 5. Range condition categories determined from computer analysis of total biomass. Field A has been grazed lightly since 1949; Field B moderately; Field C heavily; and Field D very heavily.

Table 5 summarizes these map results in area statistics form. These data show that over 90% of the sampled area of Field A is in good to excellent range condition. Most of this area is in the excellent range condition category. These results correspond quite well with the results of Johnston et al. (1971) who stated that this field was in overall excellent condition. Over 90% of the sampled area of Field B is also in good to excellent range condition. However, most of this field is in good condition. Overall Field B appears to be in better than fair condition and has a smaller percentage of the sampled area in excellent condition than is the case in Field A. These results correspond closely with the general range condition of "good" described by Johnston et al. (1971) for this field. Over 90% of the sampled area of Field C is estimated to be in good to fair range condition. None of the sampled area is in excellent condition and only 8.6% is in poor condition. Most of the area of Field C is in good condition as opposed to fair condition. Field C is definitely lower in range condition, overall, than Field B. However, the Landsat data show it to be in somewhat better condition than the Johnston et al. (1971) study showed. Either the Landsat analysis is more accurate than the data presented by Johnston et al. or overall range condition has improved slightly on this field in the eight years since their study was completed. Most of Field D was estimated to be in poor and fair range condition (i.e. 86.7% of the sampled area). The largest portion of this area is in poor condition. These results correspond very closely with the assessment of Johnston et al. (1971) that the field was in overall poor condition.

SUMMARY

The procedures outlined in this study can provide accurate range condition estimates on grassland stands in the rough fescue grasslands of western Canada for any habitat type where biomass relationships to range condition are understood. The high resolution and speed of producing biomass maps from Landsat imagery makes the method cost-effective as well.

A Landsat ratio provided a high correlation with total dry forage biomass (i.e. $r = -.84$). All other past work using Landsat imagery to estimate biomass in native grasslands has had success for only the green portion of the total standing crop. The high correlation found in this study allowed four distinct biomass classes to be distinguished throughout the biomass range studied (i.e. 70-320 g/m^2).

Automatic computer mapping of each biomass class was combined with other ecological information to provide a test of the method for estimating range condition from digital Landsat data. Range condition analysis using Landsat accurately identified the range condition of fields in the Stavely Research Substation (Canada Department of Agriculture) in southwestern Alberta which have been grazed under controlled conditions since 1949.

In one year, proper use of Landsat digital data could provide range condition information on native grasslands which would take many years to gather using conventional methodology. Landsat imagery can be used to accurately map range condition on every acre of rangeland surveyed; if this is done periodically, range condition can be monitored to establish range trend. The comprehensive, detailed data provided by Landsat can thus contribute greatly to sound management decisions which will enhance the productivity of the limited range resources remaining to feed domestic and native herbivorous animals.

TABLE 1. Linear correlations of Landsat digital band values with total wet biomass of native fescue rangeland sites in Southwestern Alberta. (Grasses and sedges = G, Forbs = F, Shrubs = S)

	Correlation Coefficient*			
Band	May 22 G+F+S (N=40)	Aug. 2 G+F+S (N=40)	Sept. 7 G+F+S (N=40)	Sept. 25 G+F+S (n=40)
4	-.21	-.68*	-.13	-.21
5	-.26	-.69*	-.24	-.20
6	+.06	+.53*	+.27	+.30
7	+.09	+.63*	+.40*	+.41*

* = significant at 99% level.

TABLE 2. Total dry forage biomass classes, differentiated using an August 2, 1979 Landsat chromaticity ratio.

Total Dry Forage Biomass Range (g/m^2)	Mean Landsat Bands 4/4+5+7 Ratio	Difference Between * Adjacent Ratio Means
70-131	.2442	
		.0188[a]
132-193	.2254	
		.0065[b]
194-255	.2189	
		.0130[c]
256-317	.2059	

* Numbers followed by the same letter are not significantly different at the 95% confidence level.

TABLE 3. Total dry forage biomass of various range condition categories for rangeland habitat types.

Rangeland Habitat Types	Total Dry Forage Biomass (g/m^2) for Rangeland Condition Categories			
	Excellent	Good	Fair	Poor
Rough fescue - Porcupine grass	235	304	285	149
Rough fescue - Idaho fescue	289	252	227	159
Rough fescue - Richardson's needlegrass	238	312	207	157

TABLE 4. Range condition categories identifiable through automatic computer mapping of total dry forage biomass.

Rangeland Habitat Types	Range Condition Categories			
Rough fescue - Porcupine Grass	Excellent-Good-Fair			Poor
Rough fescue - Idaho fescue	Excellent	Good	Fair	Poor
Rough fescue - Richardson's needlegrass	Excellent-Good		Fair	Poor

TABLE 5. Areas of range condition categories on the Stavely Research Substation, (Ref. Fig. 5).

	Proportion of Sampled Area (%)			
Range Condition Category	Field A	Field B	Field C	Field D
Excellent	51.4	35.6	0	0
Excellent to Good	14.1	32.2	1.7	0
Good	24.8	22.5	57.9	13.3
Fair and Fair to upper Poor	9.7	7.3	31.8	35.7
Poor	0	2.4	8.6	51.0
Total of Area for known Range Condition	100.0	100.0	100.0	100.0
Percentage of Field Sampled	72.3	59.4	77.4	71.5

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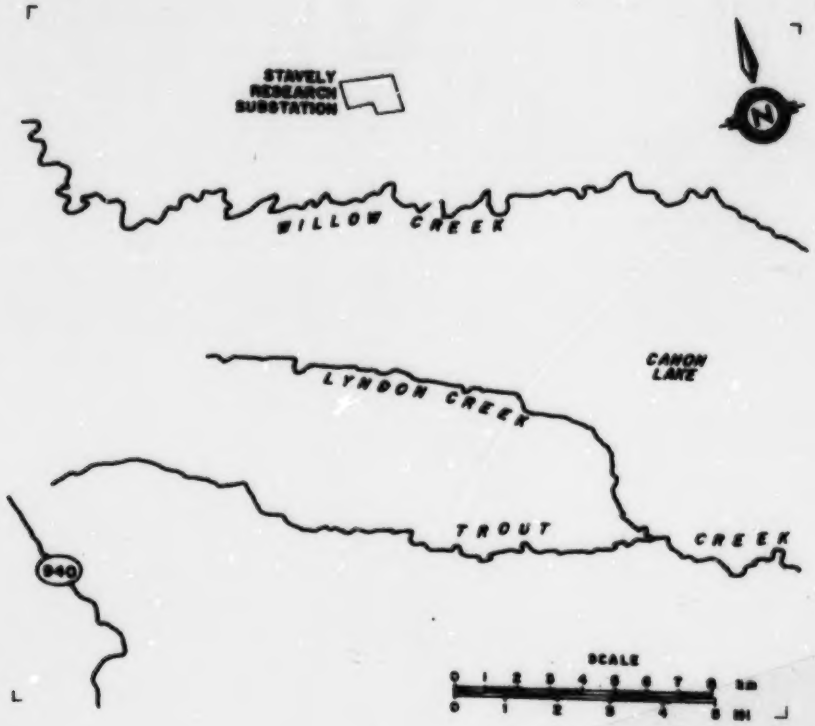

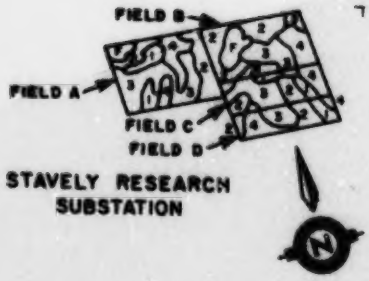

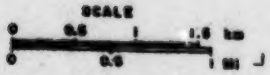

FIGURE 4 OVERLAY